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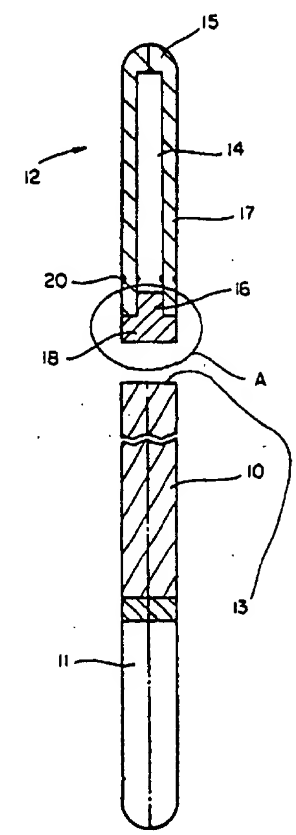
(54) Title: RADIOACTIVE SOURCE INTRODUCTION DEVICE

(57) Abstract

A device for introduction of a source of radioactive radiation (14) into a body. The device having a flexible cable (10) which can be introduced into the body and a titanium capsule (12) for sealingly containing a radioactive source (14), the capsule (12) comprising a thin walled tubular reservoir coaxially connected to the cable (10).



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RADIOACTIVE SOURCE INTRODUCTION DEVICE

The invention relates to a device for introducing a source of radioactive radiation into the body for therapeutic application, and to a capsule for said device.

Such a device is known from United States Patent Specification 3,750,653. This Patent Specification discloses a thin-walled, narrow tube which is closed at its front end and which can be introduced into the human body. The rear end portion stays outside the body, so that after positioning the tube, a source of radioactive material can be introduced into the tube. This known device shows many disadvantages, such as discomfort in use, inaccurate positioning of the source, impossibility of deep penetration into the body, and the use of plastic source-covering material unfit for accommodating a radioactive source.

The use of catheterization has expanded enormously in medicine and allows for the almost unlimited possibilities of penetrating deeply into the body of a patient. However,such possibilities are seriously restricted by the use of the device as described in the above-mentioned U.S. Patent. In particular, many places which can be reached by a catheter, for example, various internal organs, cannot be reached with the radioactive source of the device as disclosed in said U.S. Patent.

U.S. Patent 4,861,520 overcomes several of the above problems noted above, and provides a device for introducing a source of radioactive radiation into the body for therapeutic application which satisfies the following conditions:

(i) it is possible to position the source of radiation accurately with respect to the tumour to be treated;

(ii) the source of radiation is safely enclosed in a metal capsule which is resistant to the radioactive radiation; and

(iii) the device is generally applicable, i.e. is also usable in the radiotherapeutic treatment of those tumours which are difficult of access, in particular lung tumours and tumours in those internal organs which are accessible for catheterization

through the bloodstream or percutaneously.

The device described in U.S. Patent 4,861,520 comprises a flexible cable which can be introduced into the body through a catheter and which at its front end is coaxially provided with a capsule, sealingly accommodating iridium-192 in such a quantity that its activity capacity is sufficient for therapeutic application. The capsule comprises a thin-walled tubular reservoir, one end being sealingly connected to the flexible cable and a second end being closed and having a round-off external shape.

The cable must be flexible so as to be able to follow the track of the catheter. At the end of the cable remote from the capsule, a solid end portion on which information regarding the nature of the radiation source may be provided, if so desired. Cable and capsule coaxially connected thereto are proportioned so that they can be manoeuvred to the desired position through a catheter already provided in the body. This is of great importance because almost any place in the body is accessible for a catheter, such as body cavities, and other places in the body. The flexibility of the cable enables the radiation source to reach places in the body which are difficult to access, in particular the deeper-situated parts of the respiratory system, as well as other internal organs, for example, liver and kidneys, which can be reached by means of a catheter either through the bloodstream or percutaneously. The length of the capsule connected axially to the cable is of essential importance, because the capsule must be manufactured of metal and is therefore rigid.

Improvements as to the length of the reservoir can be reached, according to the recently published International Patent Application (PCT), publ. no. WO 92/00776, by using as the radioactive source a single bar of iridium-192 instead of a plurality of iridium-192 pellets, and by using iridium-192 formed by irradiation of enriched iridium-191.

Still a disadvantage of the known devices is that a number of procedures has to be performed with the "hot" capsule, i.e. the capsule already containing the radioactive source. The handling of dangerous radioactive

material during such procedures may promote a less stringent accuracy in quality control and the admittance of higher tolerances, resulting in products with a suboptimal quality. Examples of such procedures are the radioactivity measuring of the individual pellets or bar of radioactive material, the packing thereof into the capsule, the sealing of the ampoule, e.g. by welding, to accommodate the radioactive material therein, and the usual testing of the "hot" capsule, e.g. by proving the gastightness thereof.

It is the objective of the present invention to provide a device as presented in the opening paragraph, which device, while maintaining the favourable properties of the known devices mentioned hereinbefore, does not exhibit the above disadvantage.

This objective can be achieved by a therapeutic device for introducing a source of radioactive radiation into a body, comprising: a flexible cable which can be introduced into the body through a catheter; and a capsule for sealingly containing a radioactive source, said capsule comprising a thin-walled tubular reservoir coaxially connected to the flexible cable;
which device is characterized according to the present invention in that the capsule is manufactured of titanium.

As opposed to stainless steel, commonly used as the material for the capsule, a titanium capsule can be used without any objection as a cover for the inactive material, allowing said inactive material within the capsule to be converted into the desired radioactive material by irradiation with thermal neutrons in a reactor. Therefore, the titanium capsule can be filled with the inactive material, then sealingly closed and subjected to the procedures as indicated above, e.g. a gastightness test. Thereupon the capsule is irradiated to convert its inactive contents into the radioactive material, in this manner constituting the desired source of radioactive radiation. Connection of the irradiated capsule to the flexible cable produces the final device, having the intended radioactivity (radiation activity).

Surprisingly it has been found, that the radioactivity of the irradiated

capsule does not differ from that of the uncovered inactive material after the same irradiation procedure, so that the conclusion can be drawn, that the titanium capsule does not influence the results of said irradiation. This is completely different if stainless steel is used as the capsule material. Steel generates radioactive isotopes with half-lives of over 20 days, interfering with the radioactive source and therefore seriously disturbing the intended therapeutic application, and hampering the handling of the radioactive source.

Further it has been found, that a capsule made of titanium lends itself excellently to a rigid and reliable connection to the flexible cable, preferably by using a technique of welding.

To reduce the length of the capsule and consequently to improve the manoeuvrability of the device in the body of the patient, the reservoir of the capsule preferably has an open end, which is sealingly connected to the flexible cable, and a closed end with a rounded-off external shape. The bottom of the capsule can be reduced to a thickness of only 0.2 mm. In a suitable embodiment, such a capsule is provided with a plug, hermetically sealing the open end of the capsule and connectable to the flexible cable, preferably by welding as indicated above. Said plug has a reduced central portion, extending into the open end of the reservoir and sealing same. It has been found, that this central portion can be reduced to a length of only 0.1 mm to still be able to perform its sealing function.

The flexible cable is manufactured of a mechanically strong but flexible material, preferably of stainless steel. In order to achieve the desired flexibility, the cable is preferably composed of a bundle of twisted steel strands. To allow the device to reach places in the body which are difficult to access, in particular the deeper-situated parts of the respiratory system as well as other internal organs, the outside diameter of the reservoir and the diameter of the flexible cable are approximately 1.1 mm at most. Such a device can easily be introduced into the body through a catheter with an internal diameter of 1.3 mm. The wall thickness of the tubular reservoir taken into account, such a reservoir has an inside diameter of approx. 0.7 mm. To be able to

contain a sufficient radioactivity for therapeutic application, viz. of at least approximately 10 Curie, the length of the capsule reservoir should be optimized, keeping in mind that the shorter the rigid capsule the better the manoeuvrability of the device in the body of the patient.

Improvements as to the length of the reservoir, as described in the above WO 92/00776, can also be reached in the device of the present invention. The capsule may comprise a plurality of iridium-192 pellets as the radioactive source but, in order to minimize the length of the reservoir, preferably comprises a single bar of this radioactive material. In this manner a radioactive source with an activity of 11.2 Curie can be obtained, using a capsule with a reservoir internally dimensioned 0.7 x 3.8 mm, or if desired, of 13.6 Curie, using a capsule with a reservoir internally dimensioned 0.7 x 4.5 mm.

The invention also relates to a capsule for a device as defined hereinbefore, said capsule being adapted for sealingly containing a radioactive source, and which capsule is manufactured from titanium. As mentioned before, the radioactive source to be accommodated in said capsule comprises preferably iridium-192, in the form of a plurality of pellets or as a single bar,
In a preferred embodiment, said capsule comprises a plurality of iridium pellets, pressed iridium powder or a single bar of iridium, from which the radioactive source (iridium-192) is formed by irradiation. As explained hereinbefore, the irradiation of the inactive material, viz. iridium-191, does not influence the titanium wall of the capsule so that the proper functioning of the ready device is not disturbed. Preferably said inactive material is enriched iridium-191 in order to be able to minimize the internal volume of the capsule reservoir.

The invention will now be described in greater detail with reference to the drawing, in which:

Figure 1 is a longitudinal sectional view of a preferred embodiment of a device according to the invention, prior to connection of the capsule to the cable,

Figure 2 shows on an exaggerated scale a part of the device shown in Figure 1, viz. the part encircled at A, and

Figure 3 shows a longitudinal sectional view of a further preferred embodiment of a device according to the invention, now in a ready-for-use condition.

In broad outline the device for introducing a source of radioactive radiation into the body for therapeutic application, as shown in the drawing, is formed and dimensioned as the device shown in the above-mentioned WO 92/00776. The device comprises a flexible cable 10, having at its rear end a solid portion 11, and a separate capsule 12, that can be connected to the front end of the cable by welding. The flexible cable is twisted from a large number of strands of stainless steel. The cable has a diameter of approx. 1.1 mm.

A single bar 14 of inactive iridium is enclosed in the capsule 12. The capsule consists of a thin-walled tubular reservoir of titanium having an externally rounded-off distal portion 15 which is present at the front end. The open proximal end of the reservoir is sealed by means of a plug, equally made of titanium. The plug includes a first portion 16 having a reduced diameter extending within the tubular reservoir, which keeps the inactive material enclosed within the reservoir and tightly fits within the wall 17 of the reservoir. A second portion 18 of the plug is formed integrally with first portion 16 and bears with its outer edge or flange on the rear edge of the wall 17 of the reservoir.
As is clearly shown in Figure 2, the flange and the wall of the reservoir are circumferentially welded together by a weld 19, for example by electron beam welding, laser welding or orbital welding, so that a reliable and hermetic seal of the reservoir is obtained.

The capsule containing the iridium is irradiated by thermal neutrons in a reactor, resulting in the capsule enclosing the radioactive source of iridium-192. Then the plug of the capsule is connected to the flexible cable by welding it at the prepared forward end 13 of the cable, also, for example, by laser welding, electron beam welding or orbital welding.

Stringent requirements have to be imposed upon the outside dimensions of the rigid capsule 12 in order to be able to reach the deeper-situated organs in the body by passing through a catheter. A tubular reservoir

having an external length of approx. 5.0 mm, measured from the front end of distal portion 15 to the rear edge of the flange of the second portion 18 of the plug, i.e. to the end of the prepared end of the cable, and having an outside diameter of approx. 1.1 mm, is optimum, because such dimensions provide sufficient space for a quantity of radioactive material, in particular a single bar of iridium-192, with a radioactivity capacity of 11.2 Curie. The internal dimensions of the capsule reservoir are then 0.7 x 3.8 mm. If the internal length of said reservoir is enlarged to 4.5 mm, resulting in an external length of the capsule of 5.0 mm, a radioactivity capacity of even 13.6 Curie can be realized. Such quantities of radioactivity are extremely suitable for the radiation treatment of tumours of internal organs, for example, lung tumours. It should be emphasized, that the radioactivity capacities obtained by irradiation of inactive iridium enclosed within the titanium capsule, viz. the above 11.2 and 13.6 Curie respectively, are the same as can be realized by irradiating uncovered iridium.
The wall 17 of the reservoir includes a plurality of notches 20, which appear as inwardly projecting bulges. The notches 20 act to keep the iridium bar properly positioned within the reservoir, and help to avoid the risk of the iridium bar dropping out of the reservoir.

Figure 3 shows another preferred embodiment of the present invention, after the irradiated capsule has been connected to the flexible cable. In this embodiment a capsule 110, manufactured of titanium, originally including a bar of iridium, and having an open end 112 and a closed end 114, is joined after said irradiation to flexible cable 100. In particular, the closed end 114 of capsule 110 is welded to cable 100, as indicated by weld 120. The capsule 110 includes a reservoir, now containing a single bar 130 of iridium-192, which acts as a radiation source. The open end 112 of capsule 110 is hermetically sealed by means of a plug 140, equally made of titanium, which includes an elongated portion 142, for insertion into the open end 112 of capsule 110. The plug 140 further includes an extended portion 144, connected to the main body of the plug through an indented break point 146. The elongated portion 142 of plug 140 may be on approx. 0.1 mm in length, and still provide adequate sealing of the capsule 110. The extended portion 144 of plug 140 may be used as a grip portion during pull testing in order to

assure the strength and reliability of weld 120. Following a successful pull test, the extended portion 144 may be broken off from the main body of plug 140 at break point 146. The device according to this embodiment is constructed in such a manner that the length of the rigid portion may be from 0.5 to 1 mm greater than the length needed to accommodate the bar 130 of iridium-192. In particular, the rigid portion of the device according to this embodiment is approx. 4.5 mm in length. If an iridium-192 source, obtained by irradiating enriched iridium-191, is utilized, the length of the rigid portion of the device may be reduced even further.

Claims

1. A therapeutic device for introducing a source of radioactive radiation into a body, comprising: a flexible cable which can be introduced into the body through a catheter; and a capsule for sealingly containing a radioactive source, said capsule comprising a thin-walled tubular reservoir coaxially connected to the flexible cable;
which device is characterized in that the capsule is manufactured of titanium.

2. A device as claimed in claim 1, wherein the capsule is connected to the flexible cable by welding.

3. A device as claimed in claim 1 or 2, wherein the reservoir has an open end, which is sealingly connected to the flexible cable, and a closed end with a rounded-off external shape.

4. A device as claimed in claim 3, wherein the open end of the reservoir is hermetically sealed to the flexible cable by means of a plug, said plug being connected to the flexible cable, preferably by welding.

5. A device as claimed in any of the preceding claims, wherein the flexible cable is made of stainless steel.

6. A device as claimed in any of the preceding claims, wherein the outside diameter of the reservoir and the diameter of the flexible cable are approximately 1.1 mm at most.

7. A device as claimed in any of the preceding claims, wherein the radioactive source has a radioactivity capacity (radiation activity) of at least approximately 10 Curie.

8. A device as claimed in any of the preceding claims, wherein said radioactive source comprises a plurality of iridium-192 pellets or a single bar of iridium-192.

9. A capsule for a device as claimed in any of the preceding claims, said capsule being adapted for sealingly containing a radioactive source, characterized in that the capsule is manufactured of titanium.

10. A capsule as claimed in claim 9, wherein said radioactive source comprises a plurality of iridium-192 pellets or a single bar of iridium-192.

11. A capsule as claimed in claim 10, characterized in that the capsule comprises a plurality of iridium pellets, pressed iridium powder or a single bar of iridium, from which the radioactive source (iridium-192) is formed by irradiation.

12. A capsule as claimed in claim 11, wherein said iridium is enriched iridium-191.

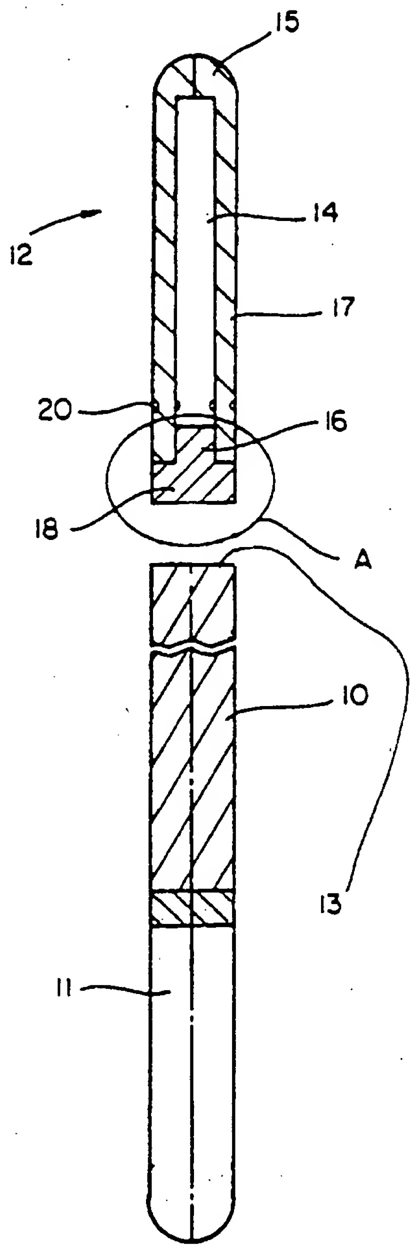

Fig. 1

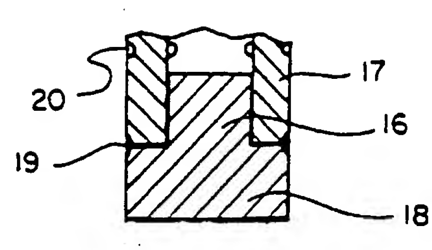

Fig. 2

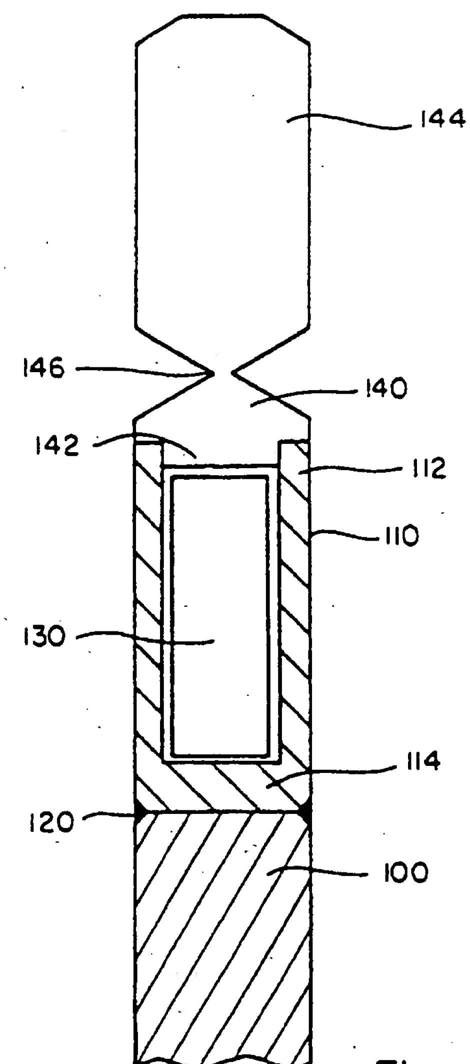

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/04213

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61M 36/00
US CL :600/7, 8
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 600/1-8

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,084,002, (LIPRIE), 28 January 1992. See entire document.	1-12
Y	US, A, 4,891,165, (SUTHANTHIRAN), 02 January 1990. See entire document.	1
X --- Y	US, A, 4,861,520, (VAN'T HOOFT ET AL.), 29 August 1989. See entire document.	1-6, 9 ---------------- 7, 8, 10-12
Y	US, A, 4,819,618, (LIPRIE), 11 April 1989. See entire document.	1-12
X	WO, A, 92/00776, (BORENMAN), 23 January 1992. See entire document.	1-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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